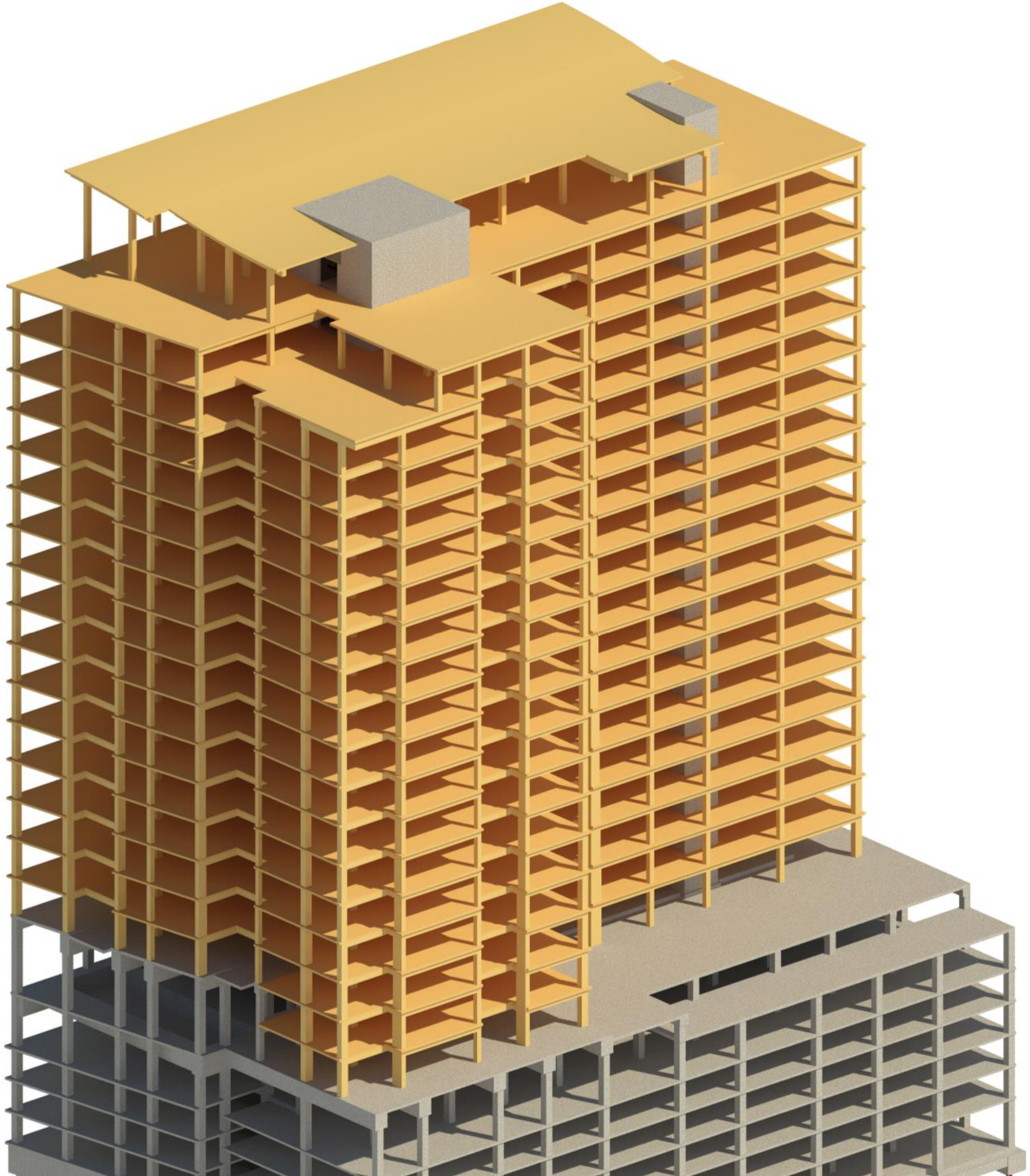

MARCH 23, 2021

Decision Making for Lowering Embodied Carbon

Scott Schneider, P.E., LEED AP

Pawel Woelke, Ph.D., P.E.

ARPA-E

Carbon Negative Building Materials Workshop

Thornton Tomasetti

AGENDA

1. A Little About Us
2. How We See The Problem
3. What Can Structural Engineers Do – How We Make Decisions
4. Current Strategies to Reduce Embodied Carbon
5. What’s Next?

A LITTLE ABOUT US

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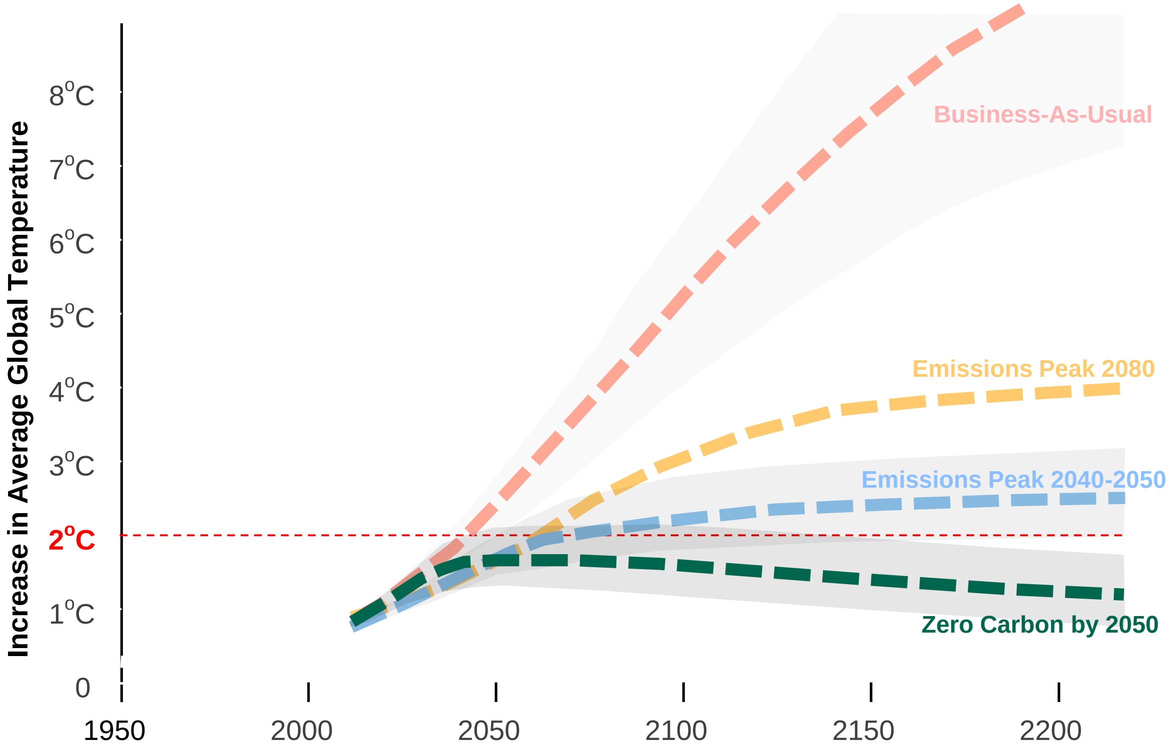
ENGINEERING SOLUTIONS

- Acoustics, Noise & Vibration
- Aviation
- Commercial & Residential
- Construction Engineering
- Critical Facilities
- Cultural & Community
- Defense
- Education
- **Energy**
- Facades
- Forensics & Investigations
- Government
- Healthcare & Research
- Hospitality & Gaming
- Insurance
- Life Sciences
- Protective Design & Security
- Resilience
- Restoration & Renewal
- Special Structures
- Sports & Public Assembly
- **Structural Design**
- **Sustainability**
- Tall & Supertall Buildings
- Transportation/Infrastructure

HOW WE SEE THE PROBLEM

- Human activities are estimated to have caused ~1.0 °C of global warming.
- Global warming is likely to reach 1.5°C (a critical threshold) between 2030 and 2050.
- We need to tackle climate change within the next 10 years or face major consequences by 2040.

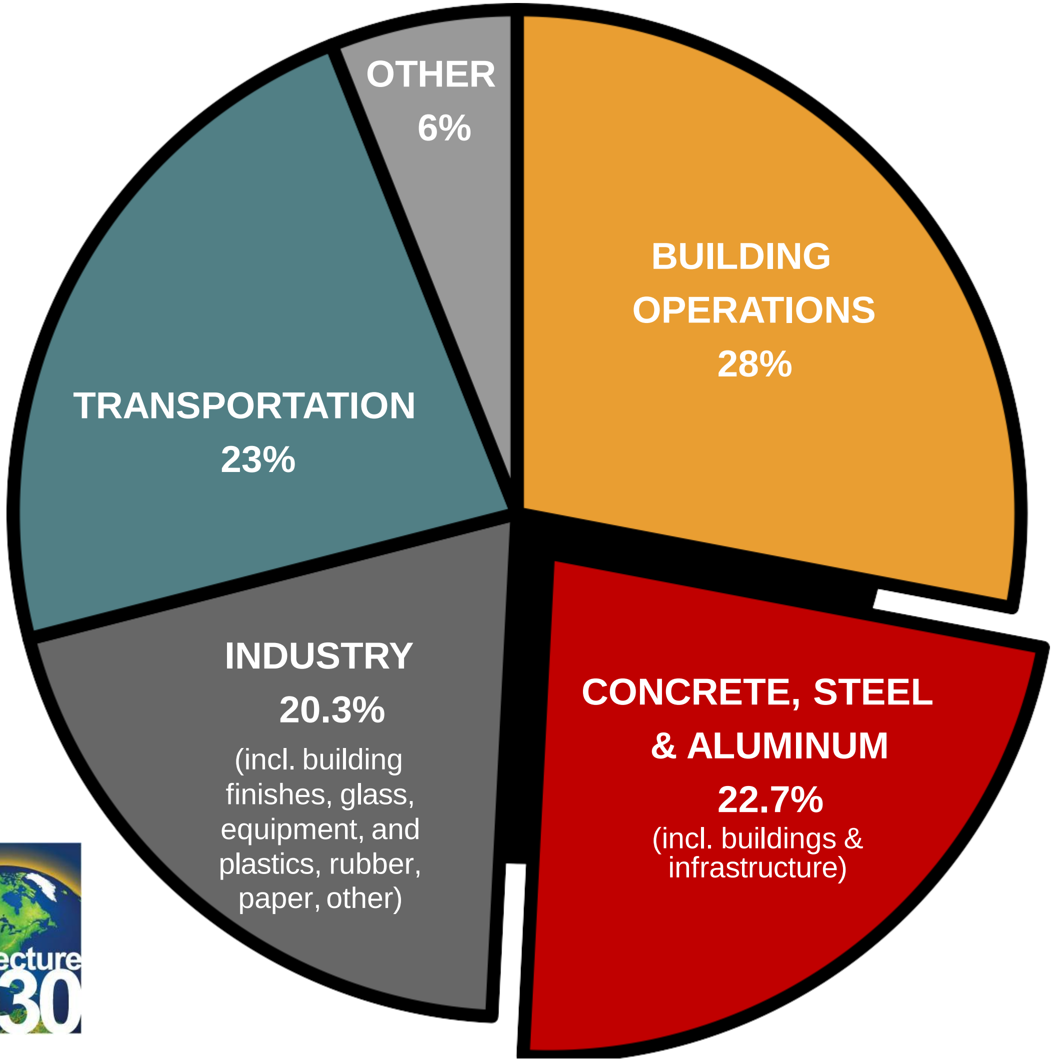


IPCC Global Temperature Projection Scenarios

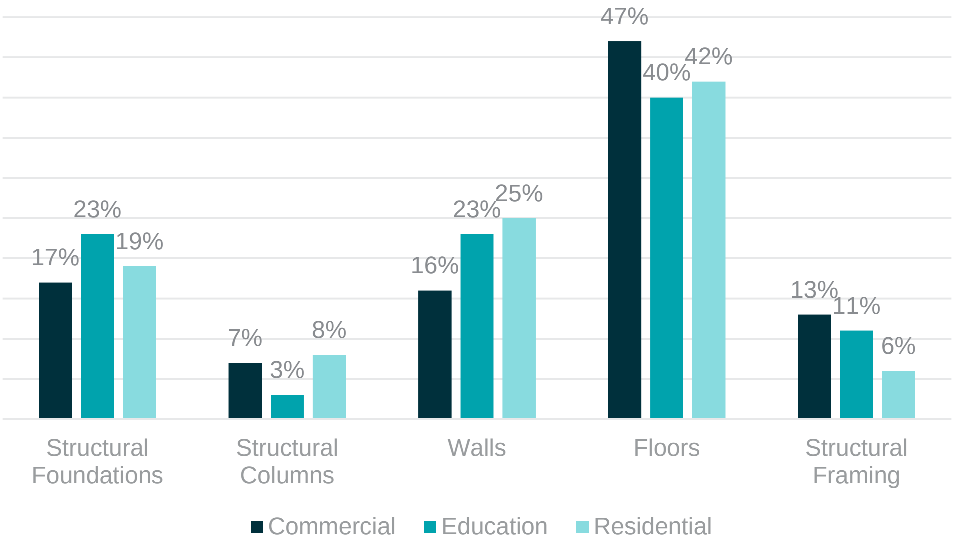
Source: IPCC 2013, Representative Concentration Pathways (RCP); Stockholm Environment Institute (SEI), 2013; Climate Analytics and ECOFYS, 2014.
Note: Emissions peaks are for fossil fuel CO2–only emissions.

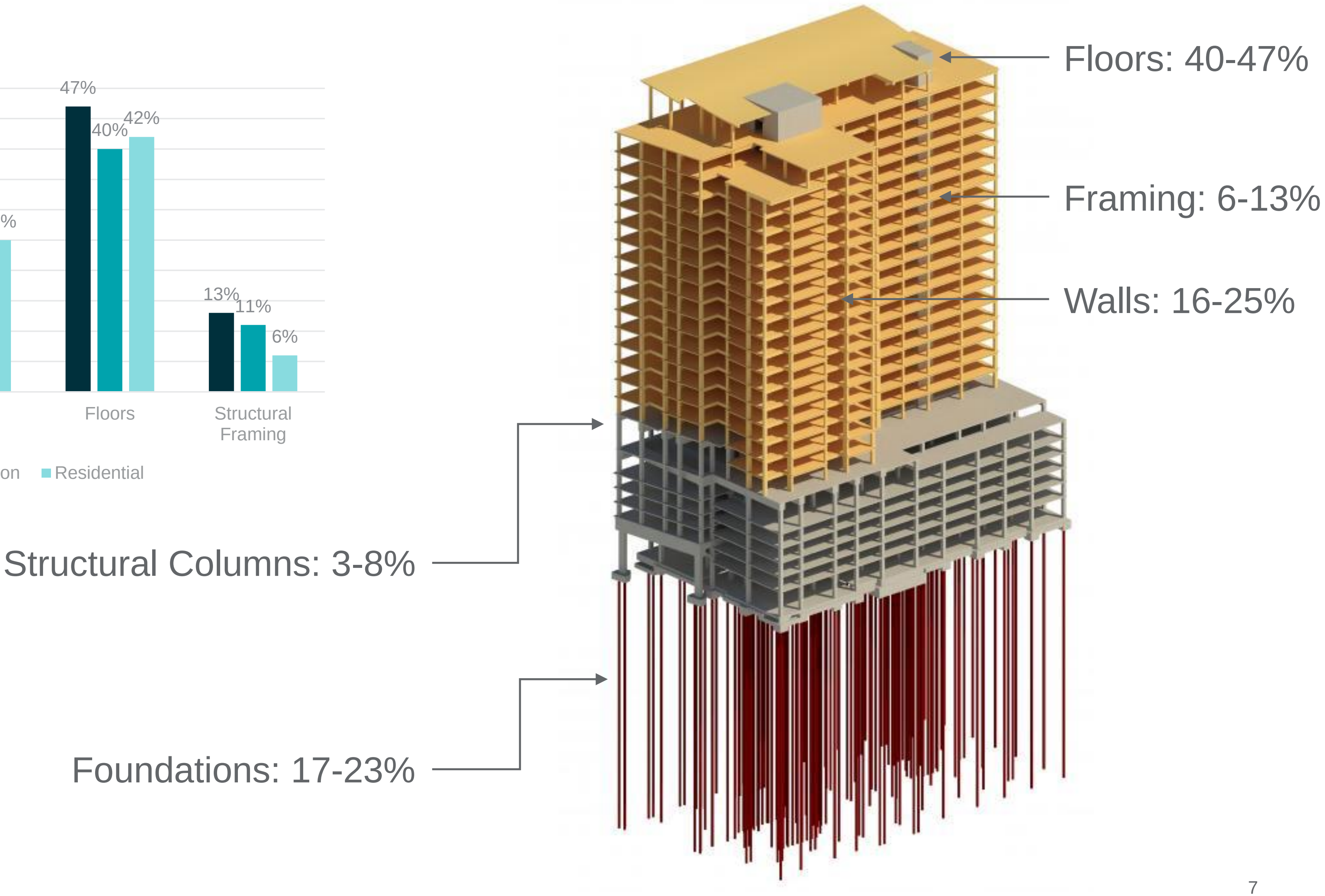
HOW WE SEE THE PROBLEM

- Global CO_2 Emissions by Sector



WHERE IS THE CARBON?

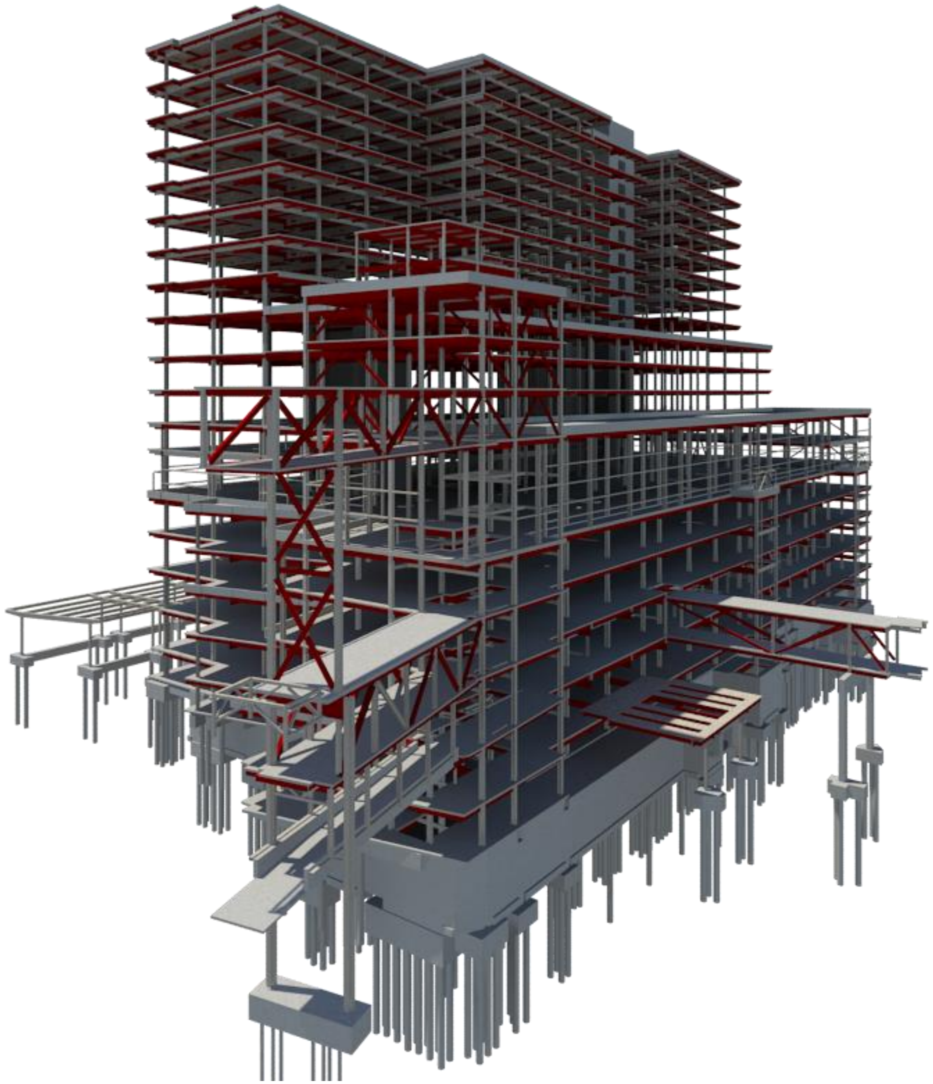




WHAT CAN STRUCTURAL ENGINEERS DO?

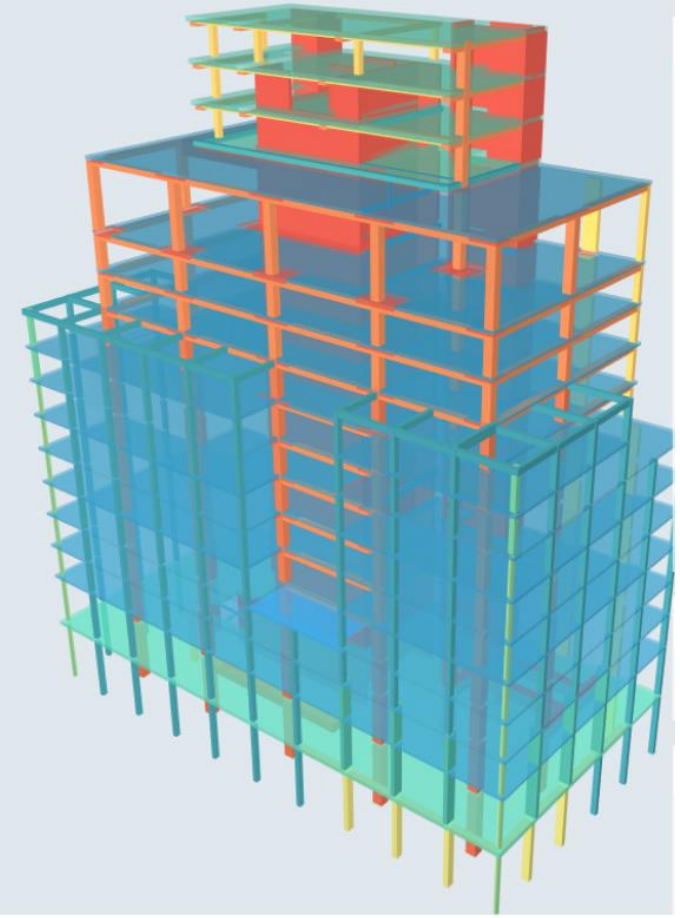
How We Make Decisions

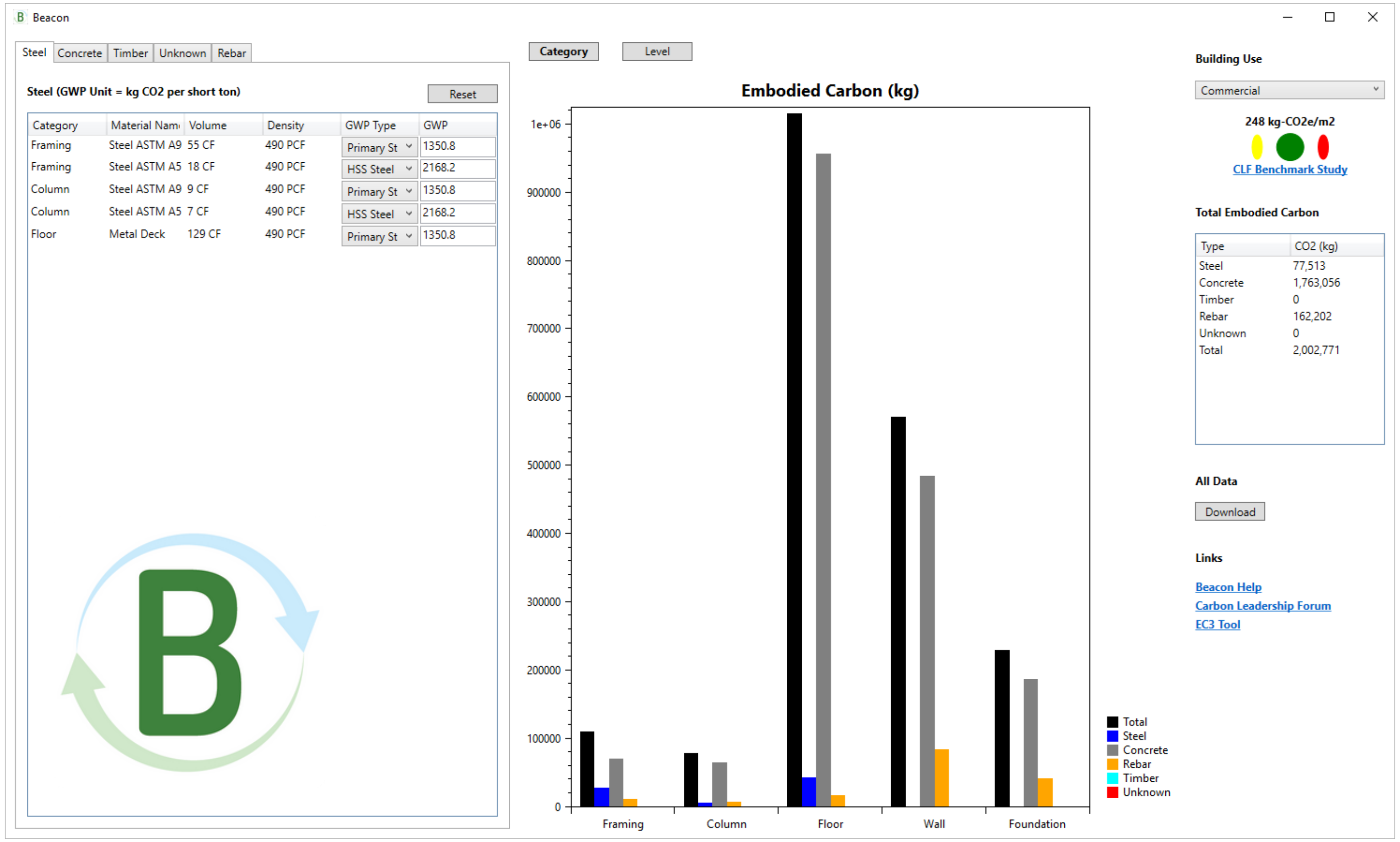
- **Safety and Comfort** – strength and stiffness requirements
- High load capacity-to-volume ratio
- Ability to create fire separation between occupied areas
- Relatively low installed cost by volume
- Relatively quick and reliable fabrication process with consistency across markets
- Relatively quick installation and skill required for erection can be taught relatively easily
- Speed and reliability on concrete strength gain (form stripping, post-tension stressing)



WHAT CAN STRUCTURAL ENGINEERS DO?

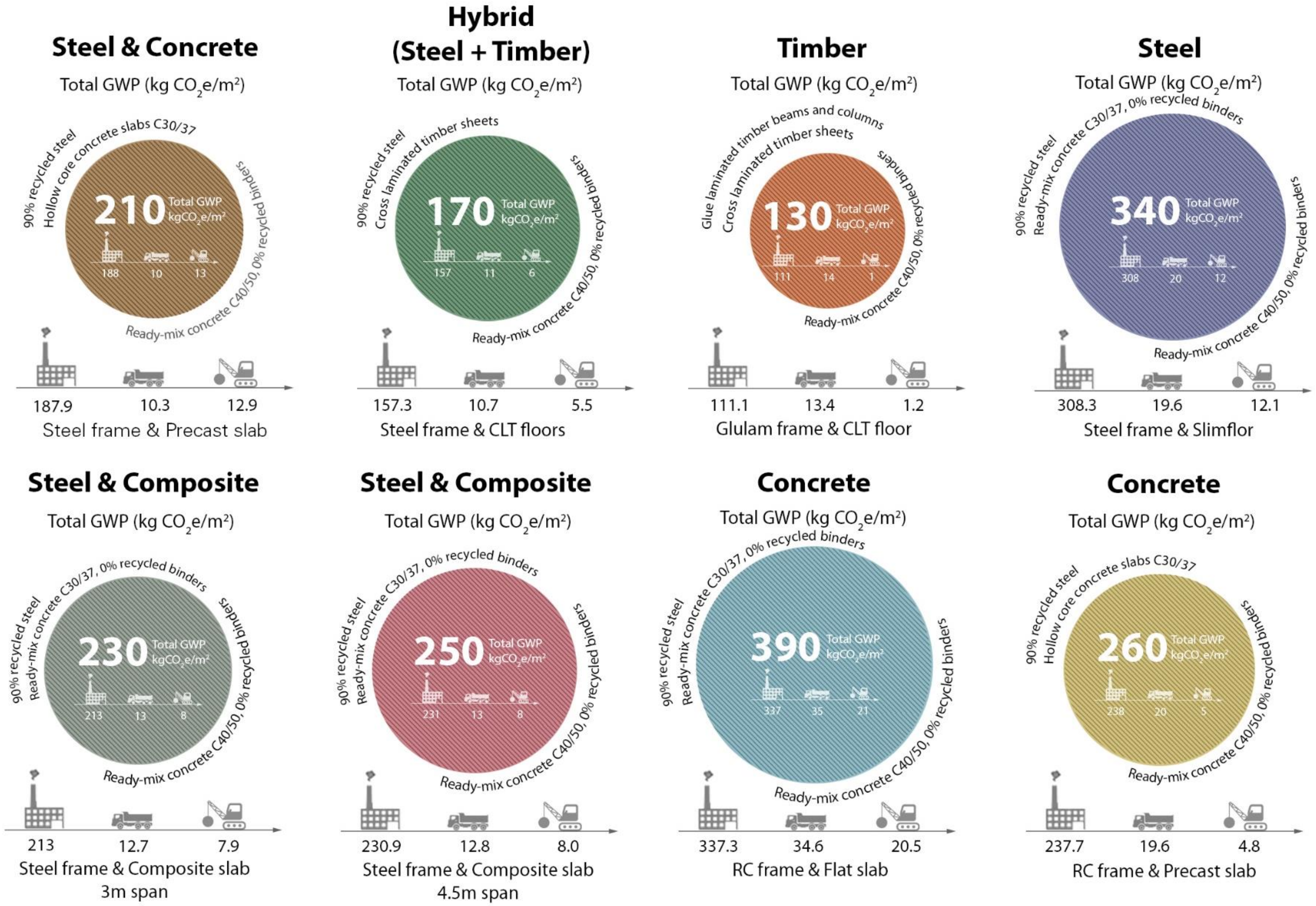
Measure Twice …





CURRENT STRATEGIES

Structural Framing Tradeoffs



MATERIALS AND SUPPLIER

Cement Replacement

FLY ASH / METAKAOLIN / SILICA FUME / FLY ASH / SLAG / CALCINE SHALE

	52%	40%	5%		
	3 KSI	4 KSI	5 KSI	6 KSI	
0% FA	264	326	523	551	
20% FA	227	279	446	470	15%
30% FA	207	254	405	426	23%
30% SL	204	251	399	420	24%
50% SL/FA	164	200	316	332	40%

UNITS IN kgCO2E / CY

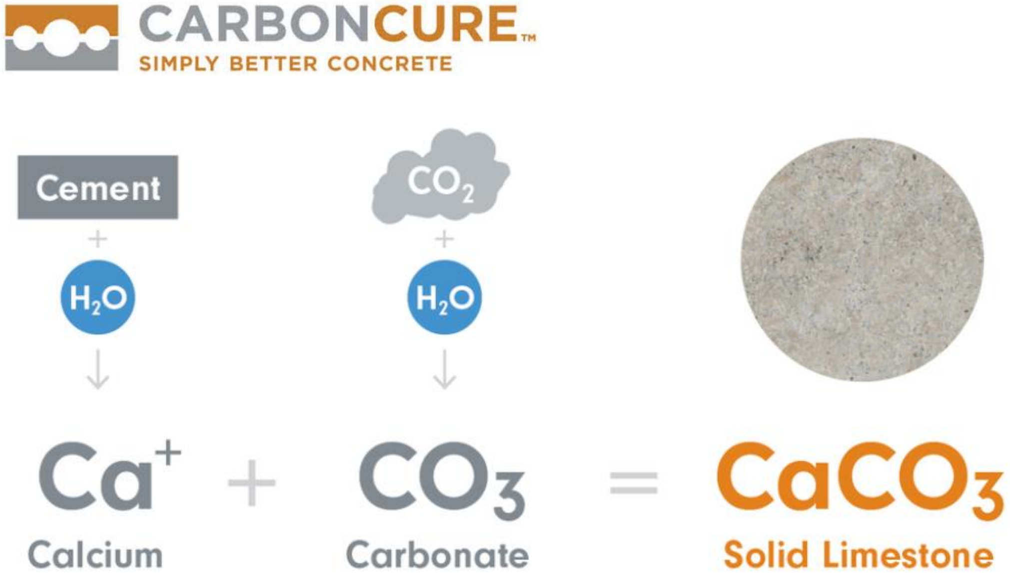
Supplier knowledge of mix performance is imperative to assignment of cement replacement:

- Strength Gain
- Workability
- Admixtures

WHAT'S NEXT?

CARBON NEGATIVE MATERIALS

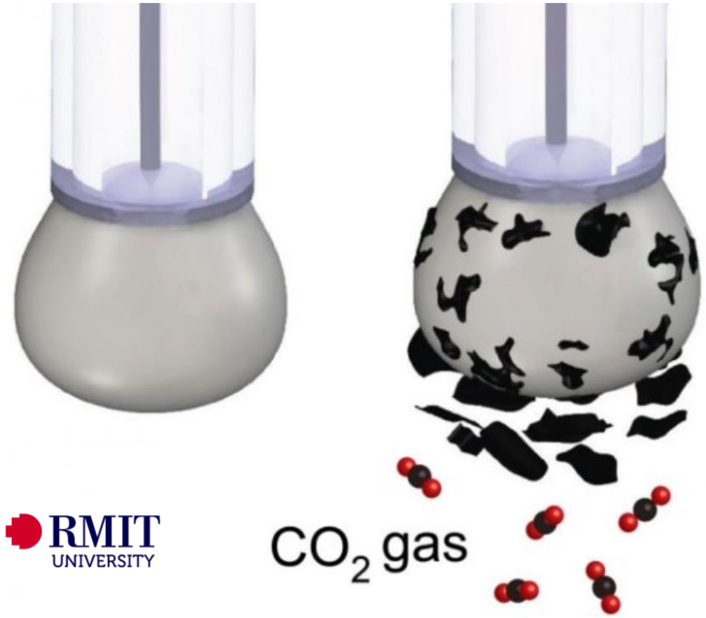
Heidelberg Cement Plant with CCS – Brevik, Norway



- ~3.3 GJ / ton of clinker (~35% production cost)
- Coal predominant fuel: ~120kg coal / ton of cement
- Circular economy: CCS → Carbon Cure tech

RE-CAPTURING CARBON

Tata Steel plant with CCS - Ijmuiden, Netherlands; eurometal.net



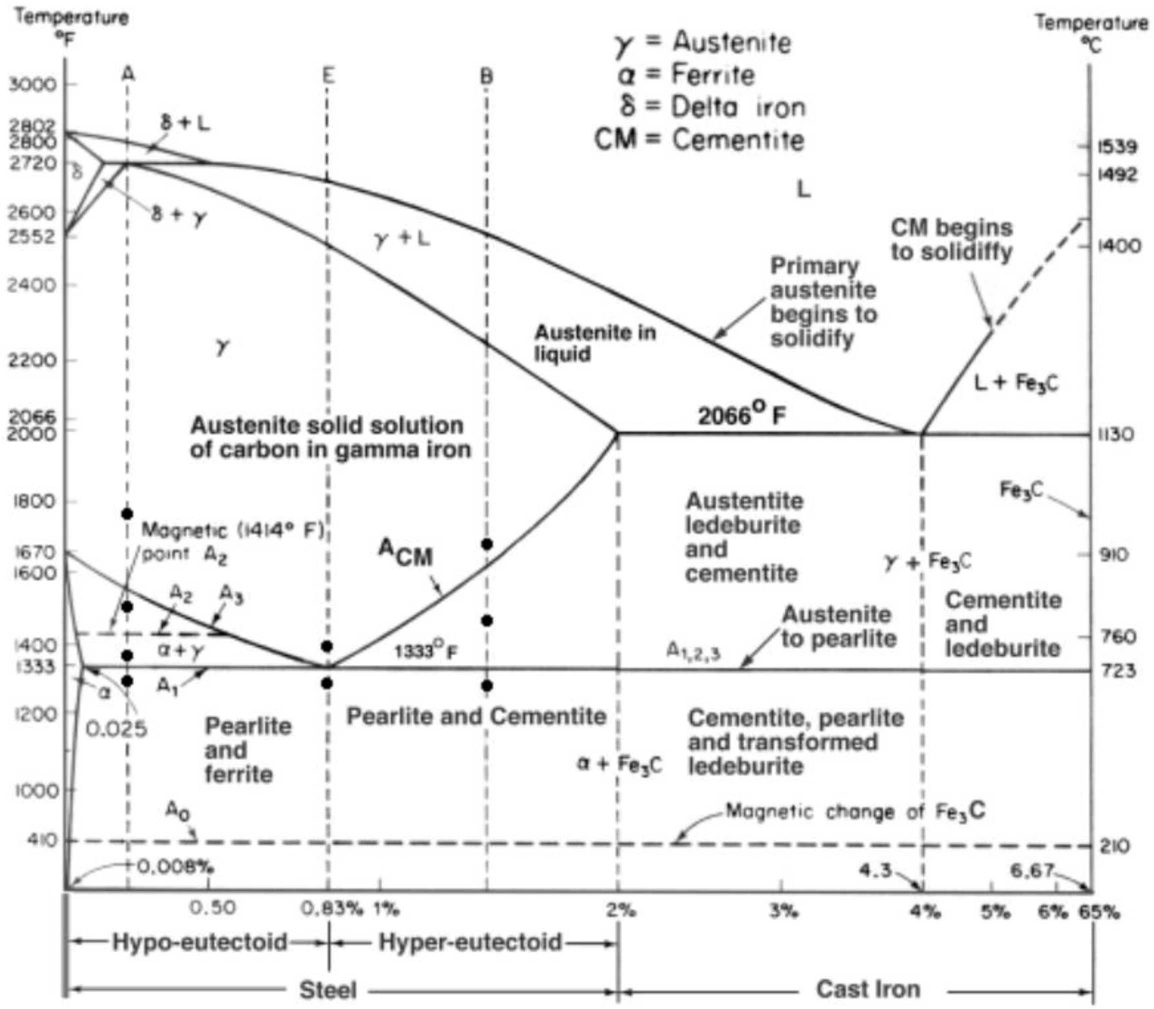
Article | Open Access | Published: 26 February 2019

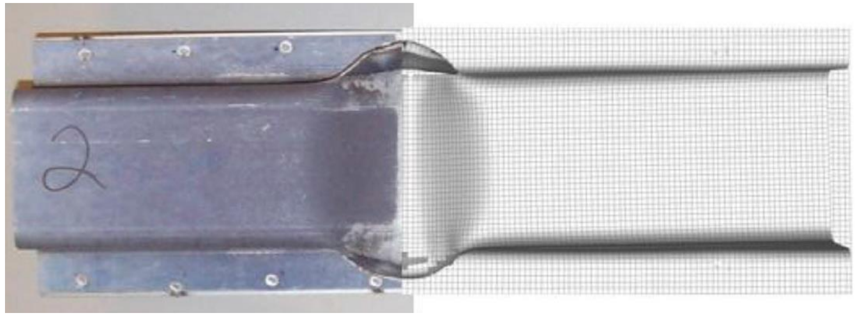
Room temperature CO_2 reduction to solid carbon species on liquid metals featuring atomically thin ceria interfaces

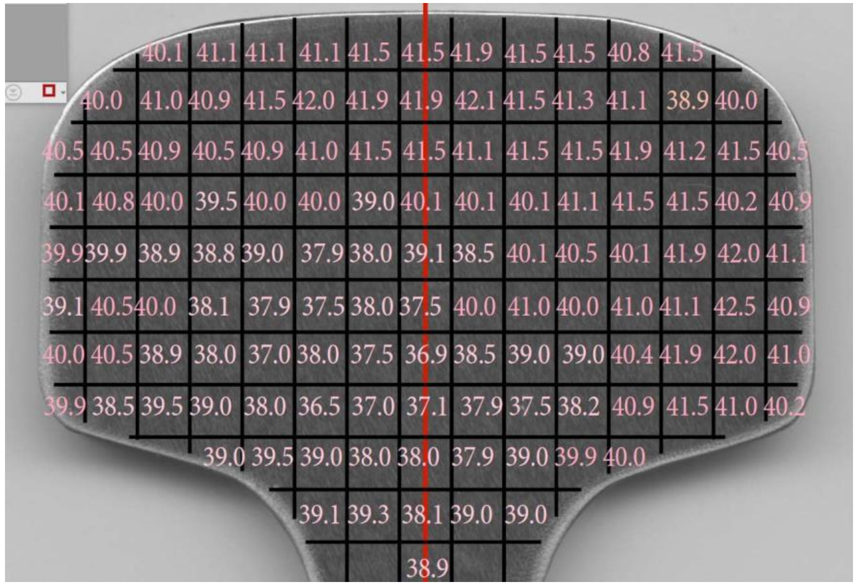
D. Esrafilzadeh et al. Nature; DOI: 10.1038/s41467-019-08824-8

- RMIT: A catalytic liquid metal alloy and CO_2, electrically charged → ***solid carbon at room temperature!***

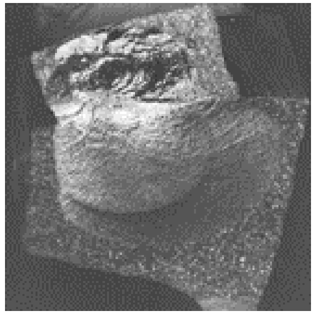
CARBON ‘HEAVY’ STEEL

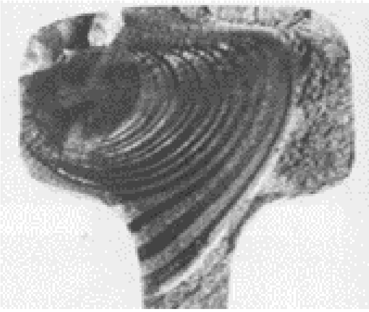


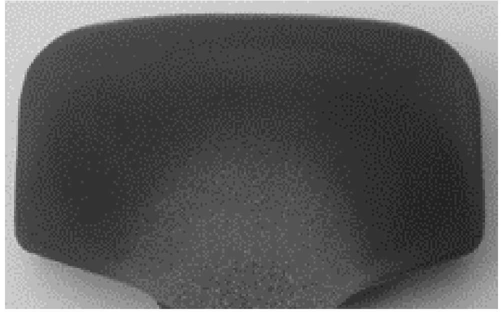




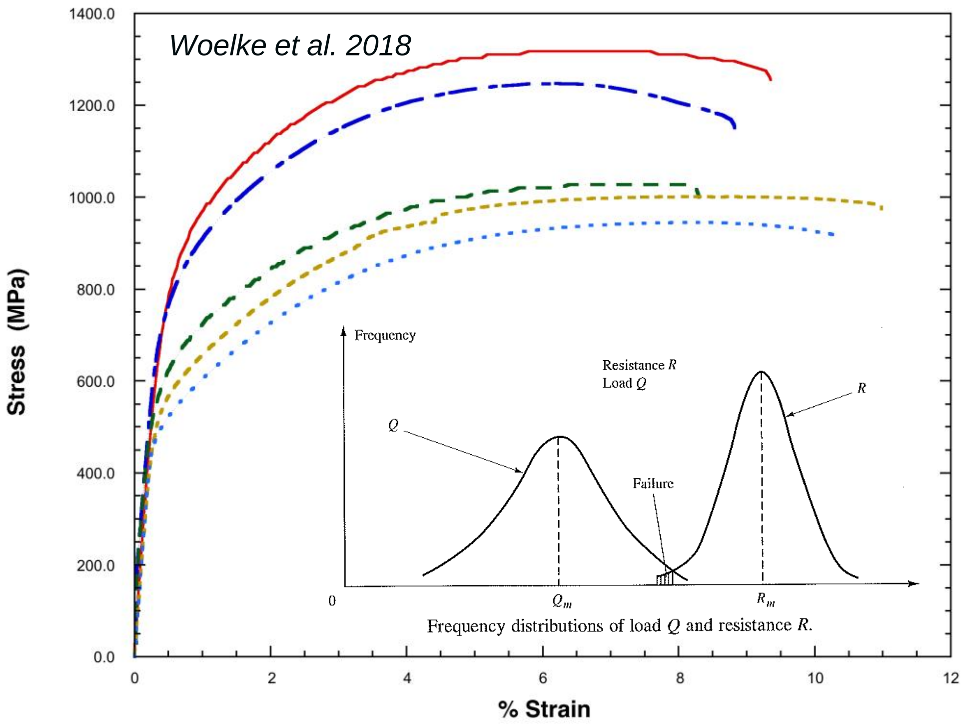
PEARLITIC STEEL

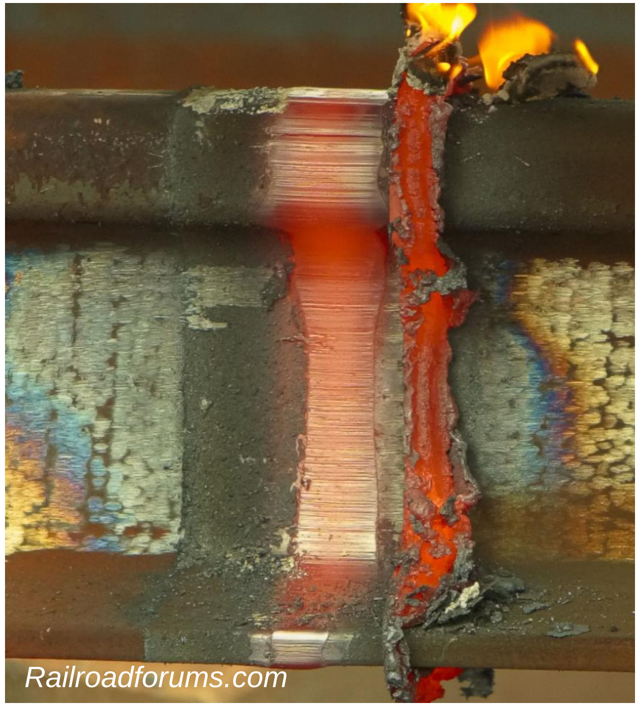






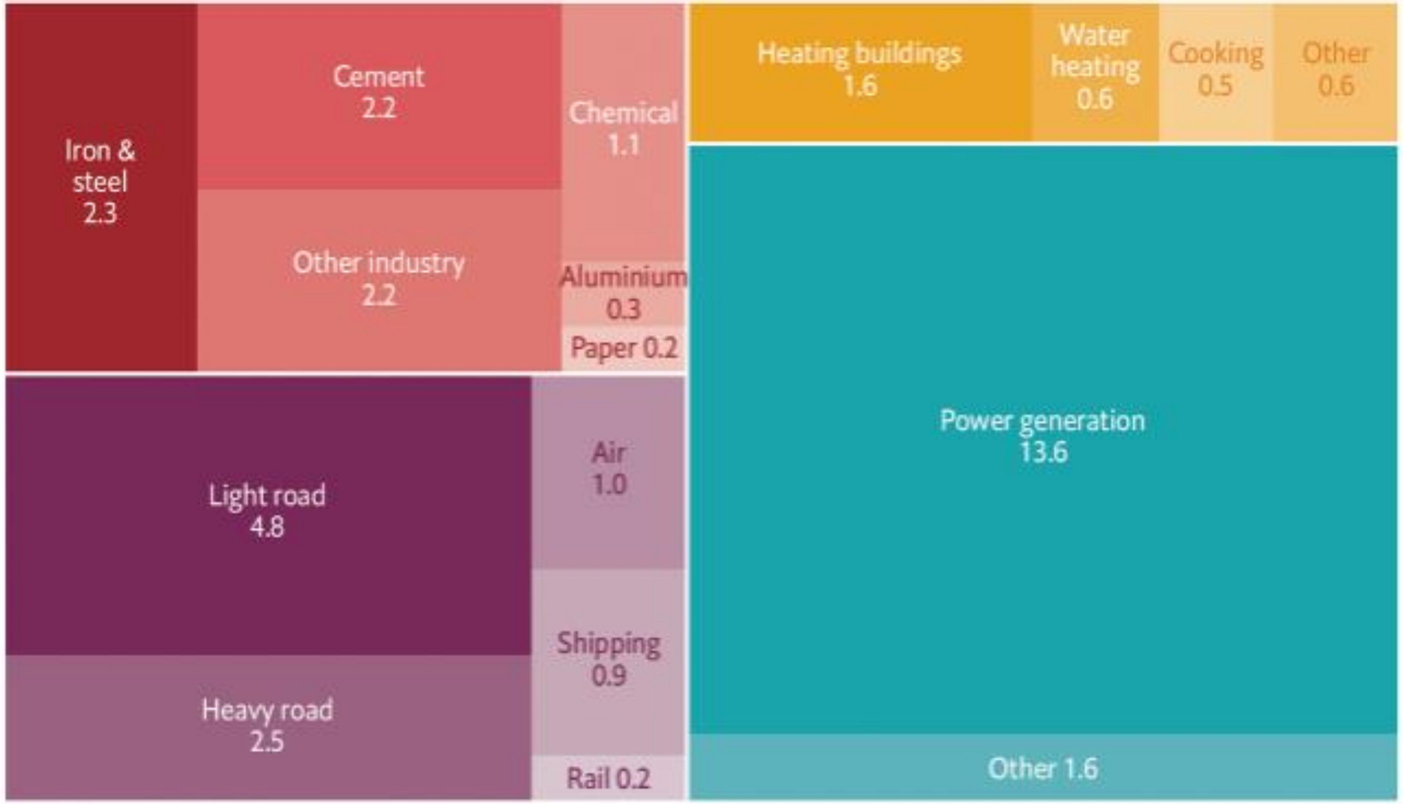
- LRFD principles could be applied – structural applications
- Challenges: manufacturing, joining, cutting, fabrication → cost increase





$$Fe_2O_3 + 2\ Al \longrightarrow 2\ Fe + Al_2O_3$$

IS IT WORTH IT?



Source: International Energy Agency / The Economist

Global energy-related CO_2 emissions, tons bn,

- Iron & steel industry global annual CO_2 emissions:

  ~2.3 bln tons

- Global annual steel production:

  ~160 mln tons

- Total annual CO_2 captured in steel:

  ~5 mln tons (0.2%)

  (assuming all C comes from CO_2)

IS IT WORTH IT?

CARBONCURE
SIMPLY BETTER CONCRETE

15kg of CO_2 / m^3

Cubic meter of steel

Carbon	Oxygen
6	8
C	O
12.011	15.9994

240kg of CO_2 / m^3

Increase only: (0.25% → 0.83%): 167kg of CO_2 / m^3

0.83% x 7850kg = 65kg of C; 65x3.67 = 240kg

THANK YOU

www.thorntontomasetti.com